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1. Your reference

MCM\21303

2. Patent application number
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3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Harada Industries (Europe) Limited
Bell Heath Way
Woodgate Business Park
Clapgate Lane
Birmingham B32 3BZ
United Kingdom

Patents ADP number *(if you know it)*

74177001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

Multiband antenna

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

MATHYS & SQUIRE
100 Grays Inn Road
London WC1X 8AL

Patents ADP number *(if you know it)*

1081001

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

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Description	8
Claim(s)	2
Abstract	1
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination and search *(Patents Form 9/77)*	ONE
Request for substantive examination *(Patents Form 10/77)*	-
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Date 10/6/99

12. Name and daytime telephone number of person to contact in the United Kingdom — Michael C Moir 0171 830 0000

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DUPLICATE

MULTIBAND ANTENNA

This invention relates to antennas, particularly but not exclusively for installation in cars or other vehicles.

With the increasing amount of media broadcasting including the new digital audio broadcasting (DAB) there is an increased need for a single antenna system to cover all bands. Ideally a system for an on car antenna should be small, low cost and unobtrusive. For most automobile communication systems a standard wire mast antenna or whip antenna is used but this is obtrusive on a car and susceptible to damage. Additional band requirements could lead to additional obtrusive antennas.

A printed or wire antenna being low profile is a good alternative and can be mounted conformally. One such form of antenna is disclosed in Helical and Spiral Antennas by Hisamatsu Nakano (Research Studies Press Ltd. 1987). Chapter II describes a two-wire square spiral antenna in which two arms of the spiral extend outwards from a feed at the centre of the spiral. This antenna radiates when the circumference of the spiral is about two wavelengths, the resultant radiation usually being circularly polarised.

The present invention adopts a completely different approach, namely a single wire spiral whose radiating bands are related to the overall length of the wire and the proximity of the successive turns of the spiral to each other.

According to the invention there is provided an RF antenna comprising a single conductor arranged in a generally spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the spiral, the other end of the spiral being open-circuited.

It will be appreciated that the spiral need not be strictly planar; for example the antenna can be conformed to a slightly curved surface such as a vehicle window or body panel. Indeed especially if the antenna is mounted in a concealed location, it could be markedly non-planar eg. in the form of a helical spiral.

Preferably the one end is the outer end.

The spiral may be circular or polygonal (regular or irregular) in outline and may for example be triangular. The triangular spiral may be irregular, or equiangular, or substantially isosceles in form.

The spacing between generally co-extensive parts of the spiral may be chosen so that the antenna has a required resonant frequency. By "generally co-extensive parts" we mean sections of the spiral which whilst not necessarily of the same length, extend generally alongside and preferably parallel to each other.

Alternatively or in addition the aspect ratio of the spiral may be chosen so that the antenna has a required resonant frequency.

Alternatively or in addition the length of the conductor forming the spiral may be chosen so that the antenna provides a required resonant frequency.

A stub antenna may extend alongside an outermost portion of the spiral to provide a required resonant frequency.

The antenna may be mounted on a substrate for attachment to a window or other surface.

The antenna may comprise a ground plane functionally adjacent the spiral conductor.

Alternatively the antenna may be in combination with a further said antenna, the two antennas being arranged as a dipole.

The invention also provides a window or vehicle body panel or other vehicle fitment comprising an antenna as set forth above.

The window or panel may form a dielectric between the antenna and the ground plane.

In another aspect the invention provides a method of manufacturing an antenna comprising disposing or defining a conductor in a spiral with a feed connection at or adjacent one end thereof and selecting the spacing between adjacent turns of the spiral, and/or the aspect ratio of the spiral and/or its overall length so that the antenna has required resonant frequencies.

The invention will now be described merely by way of example with reference to the accompany drawings wherein:

Figure 1 shows a first embodiment of the invention;

Figure 2 shows a second embodiment of the invention;

Figure 3 is a more detailed view of the antenna of figure 1;

Figure 4 shows a further embodiment of the invention;

Figure 5 shows the frequency response of the antenna of figure 3;

Figure 6 shows the frequency response of a longer antenna; and

Figure 7 shows the polar radiation pattern of the antenna of figure 3.

Figure 1 shows the basic shape of one type of antenna according to the invention. It is in the form of a triangular spiral 10 in which the included angles between adjacent sides 12, 14 are equal (60°) ie. each turn of the spiral, and the overall envelope of the spiral, is substantially an equilangular triangle.

The spiral consists of a single length of wire having a terminal for connection at its outer end 18 to one conductor of a co-axial transmission line. The antenna is disposed adjacent a ground plane 20, which has a terminal 22 for connection to the other (shielding) conductor of the co-axial line. Alternatively a coplanar pair or other suitable transmission line may be used.

The spiral 10 may conveniently be printed on or embodied in the rear or other window of a motor vehicle, by known techniques, the ground plane 20 being provided by an adjacent metal panel of the car body in which the window is fitted.

Thus in particular the roof of the vehicle can be utilised as the ground plane. With the increasing use of plastics or other non-metallic materials for vehicle body panels and bumpers (fenders) and other vehicle body fitments, it alternatively may be convenient to embody the antenna on or in one of these parts. The antenna could be provided as a wire enclosed in a flexible film for this purpose.

The lowest (fundamental) resonant frequency is determined by the overall length and number of turns of the spiral. Because the position of the outer end is determined by the terminal 18, the innermost side of the spiral 24 may be foreshortened, eg. in figure 3.

A stub antenna 26 is provided alongside and parallel to the outermost side 28 to provide another resonant frequency, as discussed further below. Further stub antennas may be provided, preferably extending generally parallel to antenna 26 to provide yet further resonant frequencies in other bands, The resonant frequency of the stub antenna is determined primarily by its length, but may also be affected by reactive coupling to an adjacent portion of the antenna.

An alternative form of antenna is shown in figure 2. Here two triangular spirals 10 as already described are arranged relative to each other so as to form a dipole, the ground plane being dispensed with. The terminals 18, 20 preferably are connected to a balanced transmission line or to a twisted pair with balun, as known per se.

Referring to figure 3, the dimensions of the spiral 10 of figure 1 are given, as determined in a prototype which gives mixed polarisation coverage for the following bands:

AM (140-283KHz & 526-1607KHz)
FM European (88-108MHz) or Japan 76-90MHz)
DAB1 (217.5-230MHz)
DAB2 (1452-1492MHz)

Other frequency bands can be covered by choosing suitable dimensions for the structure, as discussed below. The antenna can incorporate an amplifier to give increased sensitivity at each band.

The side projection stub 26 provides matching at the higher frequency band and the remaining spiral geometry sets the lower frequency bands. The resonant frequencies of the triangular spiral can be changed by varying the values of h (the height of the antenna) and d (the conductor spacing). By varying the value of d the inductance between adjacent parts of the antenna changes and hence the loading of the structure changes, thereby changing the effective electrical length of antenna. The overall length of the line constituting the spiral antenna also can be increased or decreased thus changing the operating band frequencies and the number of operating bands. The geometry may also change so that the number of turns on the spiral increases or decreases, depending on the overall length.

The spiral shown in figure 3 has equal angles. If the angles are changed, hence changing the aspect ratio, for example as shown in figure 4 so that the shape becomes akin to an isosceles rather than an equilangular triangle, then the ratio of vertical polarisation to horizontal polarisation power radiated will change. This is useful where mixed polarisation broadcasting is used such as FM radio and TV in the UK and provides easy adjustment with this type of antenna.

The synthesis of an antenna design from first principles is mathematically complicated, and design can with advantage be approached empirically. The main principles are as follows:

The overall length of conductor in the spiral determines the lowest operating frequency, hence a long antenna will operate at a lower frequency while a short antenna will operate at a higher frequency.

The stub 26 determines the frequency of the highest band - it resonates as a $\lambda/2$ monopole.

The gap between the adjacent turns or parts thereof affects several parameters. In effect the gap determines the mutual coupling between the conductors:

- a narrow gap leads to a shorter antenna;
- the gap width tunes the intermediate frequency band;
- the width of the gap determines the frequency bandwidth at the lower bands - increasing the gap increases the bandwidth;
- differential gaps can be set between the sides - in other words the gaps are not all equal between each arm - this allows adjustment of the bandwidths of different frequency bands.

Figure 5 plots the resonances of the antenna of figure 3. There are resonant frequency bands near 100MHz, 220MHz and 1470MHz. The AM band does not utilise a resonant structure. Figure 6 shows the effect of increasing the overall length from 65mm as in figure 3 to 110mm. The number of resonances increases with new resonances at 370 and 480MHz, and the lowest frequency of resonance reduces to 40MHz.

Sensitivity (gain) tests show that the performance of the antenna is comparable with mast antennas. The bandwidth at all bands can be improved with an active matching circuit which can also provide gain and hence the possibility of improved sensitivity.

The radiation patterns in figure 7 show the comparison between the triangular spiral antenna of figure 3 mounted on the rear passenger side window of a car and a reference monopole mounted on the roof of the same car. The gain of the active spiral is higher than that of the monopole except for a null near 40° due to blocking by the c-pillar on the car. The pattern off-car is symmetrical and very similar to a monopole.

Figures 8 to 12 further illustrate the effects of varying the overall length of an equiangular triangular spiral antenna and the spacing of its turns. Each plot is of return loss (dB) against frequency (MHz) of an antenna configured as in Figure 8c. The return loss equates to the matching of the antenna VSWR, the deeper and wider the nulls (more negative on the plot), the better the matching and the bandwidth.

Figure 8c shows the return loss of an antenna having an overall length of 135mm, and a separation d of 10mm. Figure 8b shows the return loss for the same antenna with d

increased to 15mm. This results in a deeper null at 95MHz, (ie. better matching of the resonance to the European FM broadcast band) and a slightly improved bandwidth. However the resonance 275MHz is much more dependent on the spacing d and is moved to about 220MHz, and is made much wider, resulting in better matching of the antenna to the DAB 1 band over a wider bandwidth.

The resonance for the European FM band can be maintained for varying antenna lengths by varying the spacing d. Increasing d with length can maintain this resonance at an approximately constant frequency, but the higher resonance at 200 + MHz moves, so this resonance effectively can be tuned. Thus, figures 9 (length = 63mm, d = 3mm), figure 10 (length = 100mm, d = 5mm), figure 11 (length = 177mm d = 20mm) and figure 12 (length = 195mm d = 25mm) and also figure 8b (length = 135mm d = 15mm) show that an antenna for the European FM band (88-108 MHz) and the DAB 1 band (217.5-230 MHz) can be achieved with various combinations of antenna length and spacing. Thus there is considerable flexibility to tailor the antenna to the space available.

Several variations based on the foregoing principles are evident. For example the spiral may be in the form of an irregular triangle (adjacent parts of each turn of the conductor remaining parallel) or the spiral may be arranged in some other regular or irregular polygonal shape. A square or rectangular spiral for example will behave similarly to a triangular one. Indeed in the limiting case the spiral may be circular or, in order to vary its aspect ratio, elliptical or ovoid (egg-shaped, with one end more pointed than the other). In each case the principle remains to determine resonant frequencies by adjusting the overall length, and/or the spacing of the adjacent parts of the conductor, and/or by adjusting the aspect ratio. Adjacent lengths of conductor should normally be generally parallel, although non-parallel configurations may be found advantageous in some cases eg. for control of bandwidth.

Still in accordance with the foregoing principles, the antenna feed may be at the inner end of the spiral rather than the end. In that case the stub antenna 26 also is arranged at the inner end of the spiral.

Each feature disclosed in this specification (which term includes the claims) and/or shown

in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features.

Statements in this specification of the objects or advantages of the invention relate to preferred embodiments of the invention, but not necessarily to all embodiments of the invention falling within the claims.

CLAIMS

1. An RF antenna comprising a single conductor arranged in a generally spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the spiral, the other end of the spiral being open-circuited.

2. An antenna as claimed in claim 1 wherein the one end is the outer end.

3. An antenna as claimed in claim 1 or claim 2 wherein the spiral is circular.

4. An antenna as claimed in claim 1 or claim 2 wherein the spiral is polygonal.

5. An antenna as claimed in claim 4 wherein the envelope (as defined) of the spiral is a regular polygon.

6. An antenna as claimed in claim 4 wherein two included angles between successive sides of the polygonal spiral are equal.

7. An antenna as claimed in claim 4 wherein the spiral is triangular.

8. An antenna as claimed in claim 7 wherein each turn of the triangular spiral is substantially in the form of an isosceles or equilateral triangle.

9. An antenna as claimed in any preceding claim wherein the spacing between generally co-extensive parts of the spiral is chosen so that the antenna has a required resonant frequency.

10. An antenna as claimed in any preceding claim wherein the aspect ratio (height to width ratio) of the spiral is chosen so that the antenna has a required resonant frequency.

11. An antenna as claimed in claim 4 or any claim dependent from claim 4 wherein the length of the conductor is chosen so that the antenna has a required resonant frequency.

12. An antenna as claimed in any preceding claim wherein a stub antenna extends alongside an outermost portion of the spiral to provide a required resonant frequency.

13. An antenna as claimed in any preceding claim, comprising a ground plane functionally adjacent the spiral conductor.

14. An antenna as claimed in any of claims 1 to 12 in combination with a further said antenna, the two antennas being arranged as a dipole.

15. An antenna as claimed in any preceding claim, mounted on a substrate for attachment to a window or other surface.

16. A window or vehicle body panel or other vehicle fitment comprising an antenna as claimed in any preceding claim.

17. A window or vehicle body panel or other vehicle fitment as claimed in claims 13 and 16 wherein the window or body panel forms a dielectric between the antenna and the ground plane.

18. A method of manufacturing an antenna comprising disposing or defining a conductor in a spiral with a feed connection at or adjacent one end thereof and selecting the spacing between adjacent turns of the spiral, and/or the aspect ratio of the spiral and/or its overall length so that the antenna has required resonant frequencies.

19. An antenna, a window or a vehicle body panel substantially as herein described with reference to and/or as shown in the accompanying drawings.

ABSTRACT

An RF antenna comprising a single conductor arranged in a generally spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the spiral, the other end of the spiral being open-circuited.

(figure 1)

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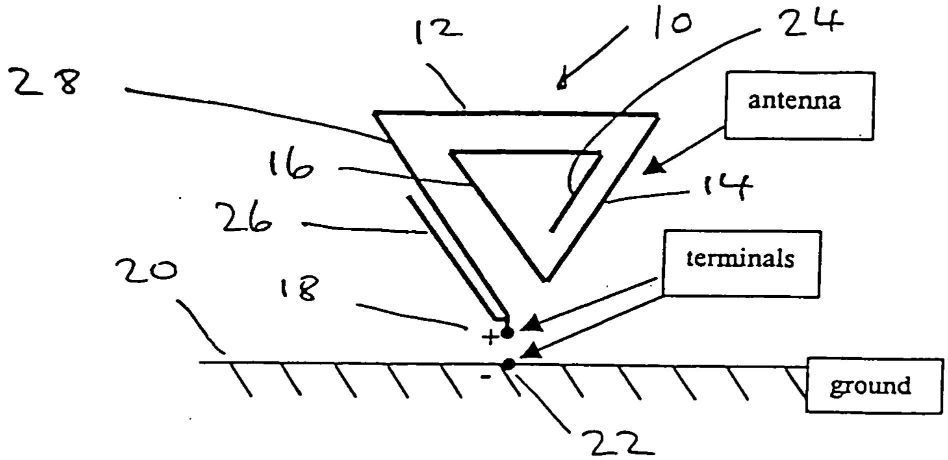

Fig.1Geometry of antenna

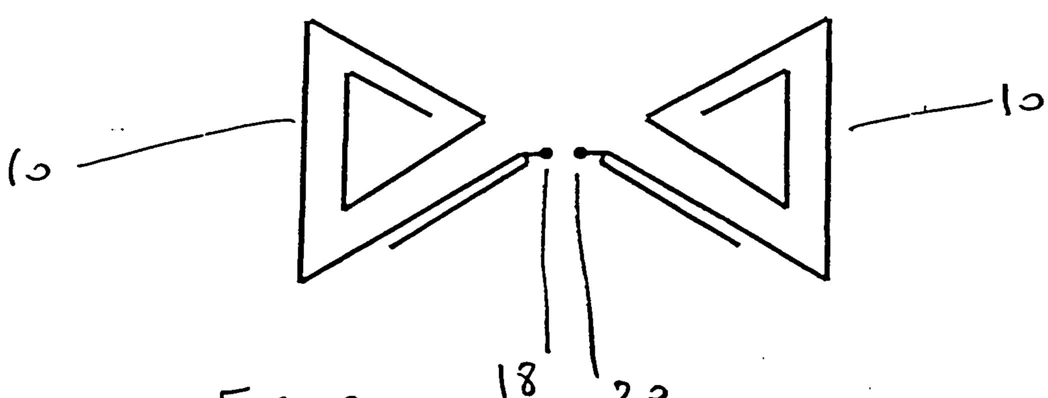

FIG 2

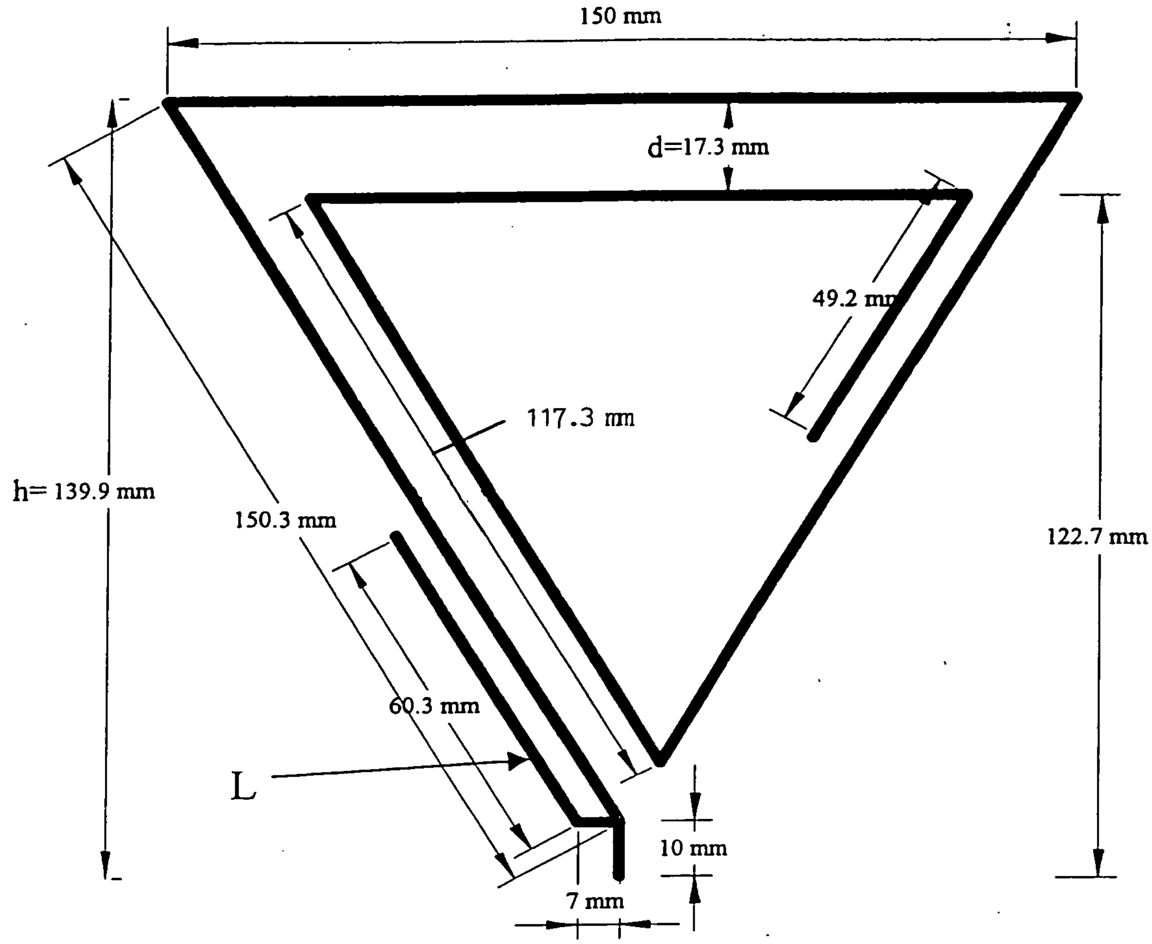

Fig.3 Geometry of antenna

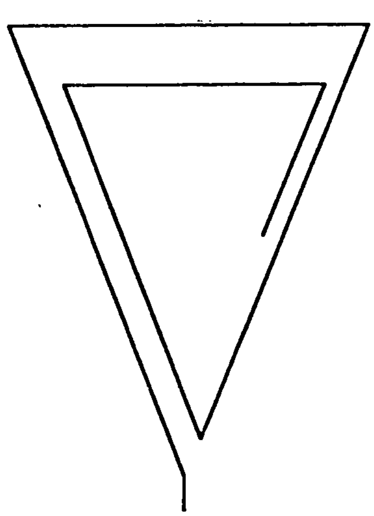

Fig.4 Non equilateral angle spiral

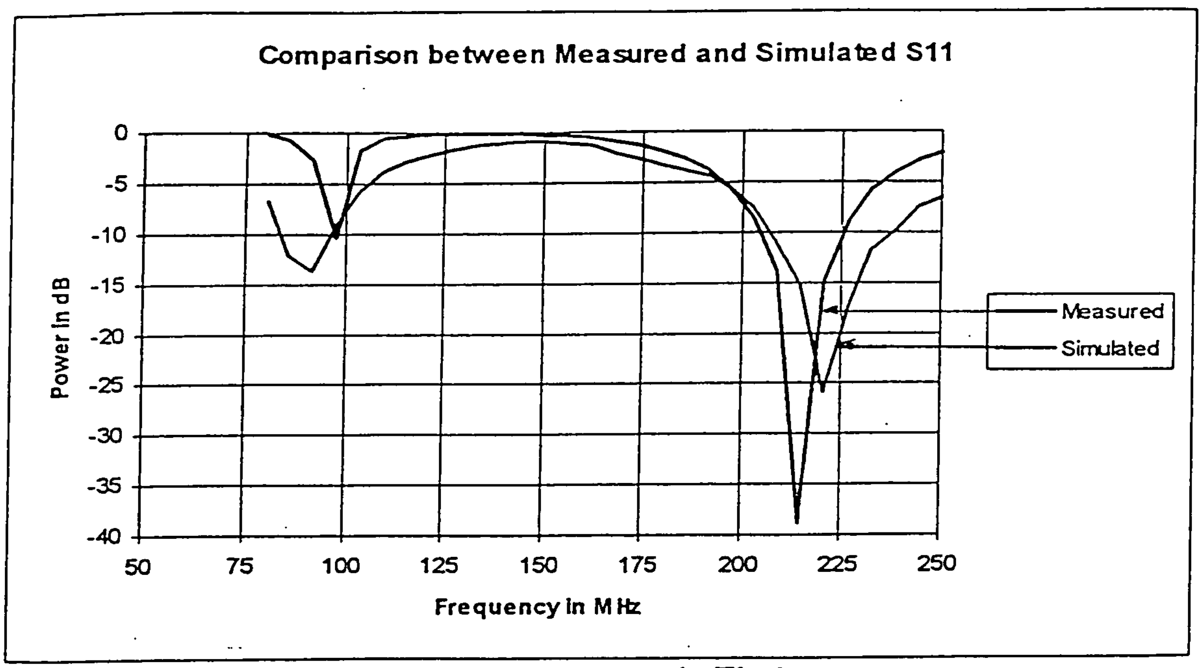

Fig.5 Resonant frequencies of antenna shown in Fig.3

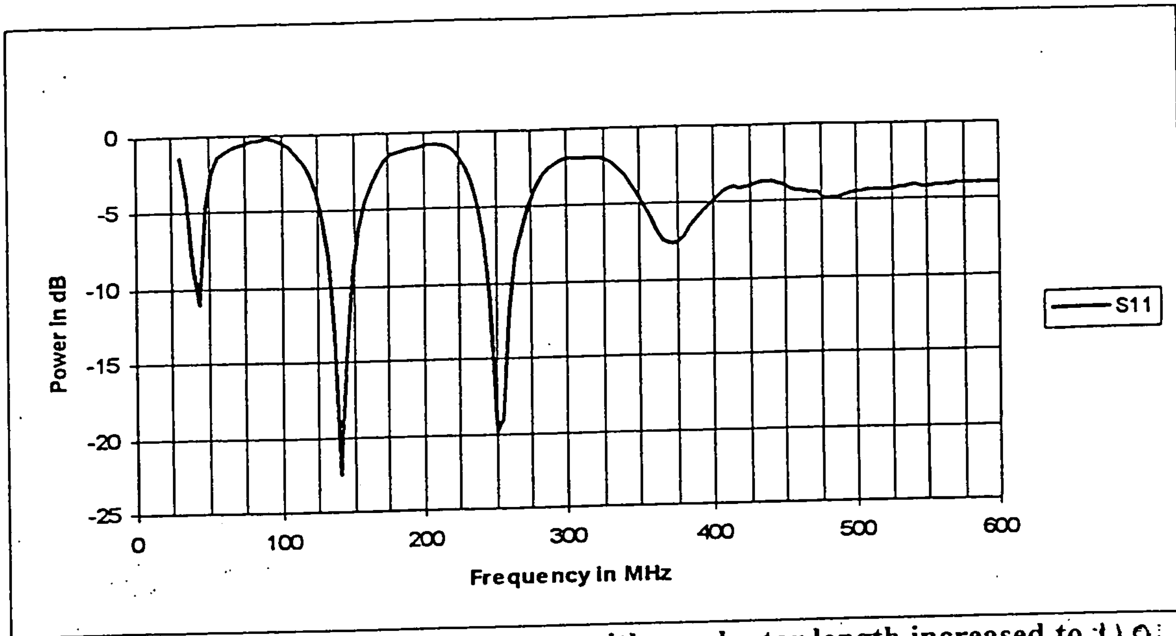

Fig.6 Resonant frequencies of antenna with conductor length increased to 110 mm

Radiation Pattern For Triangular Spiral

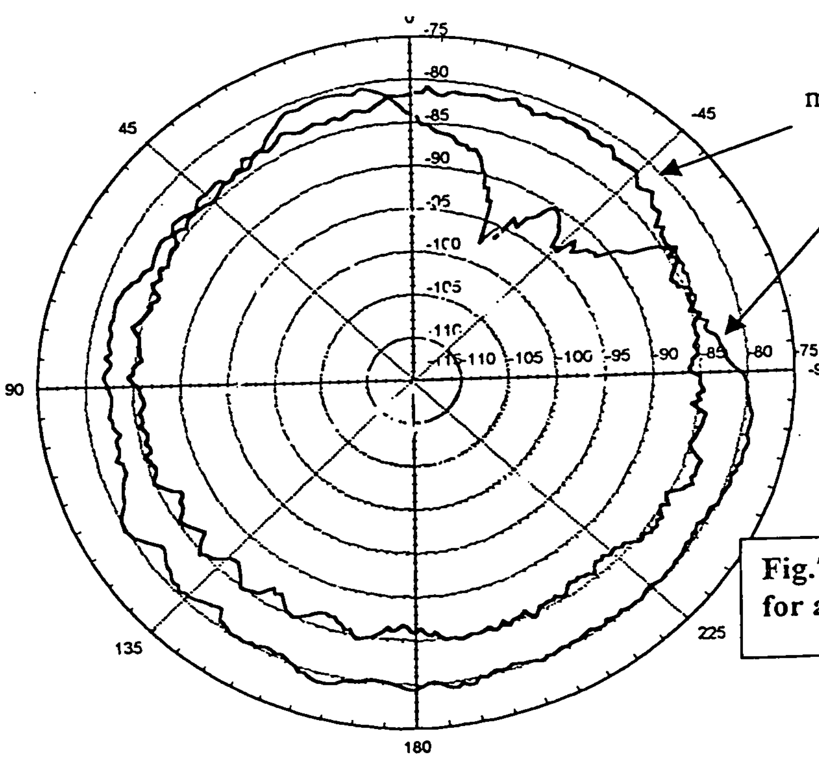

Fig.7 Radiation patterns for antenna

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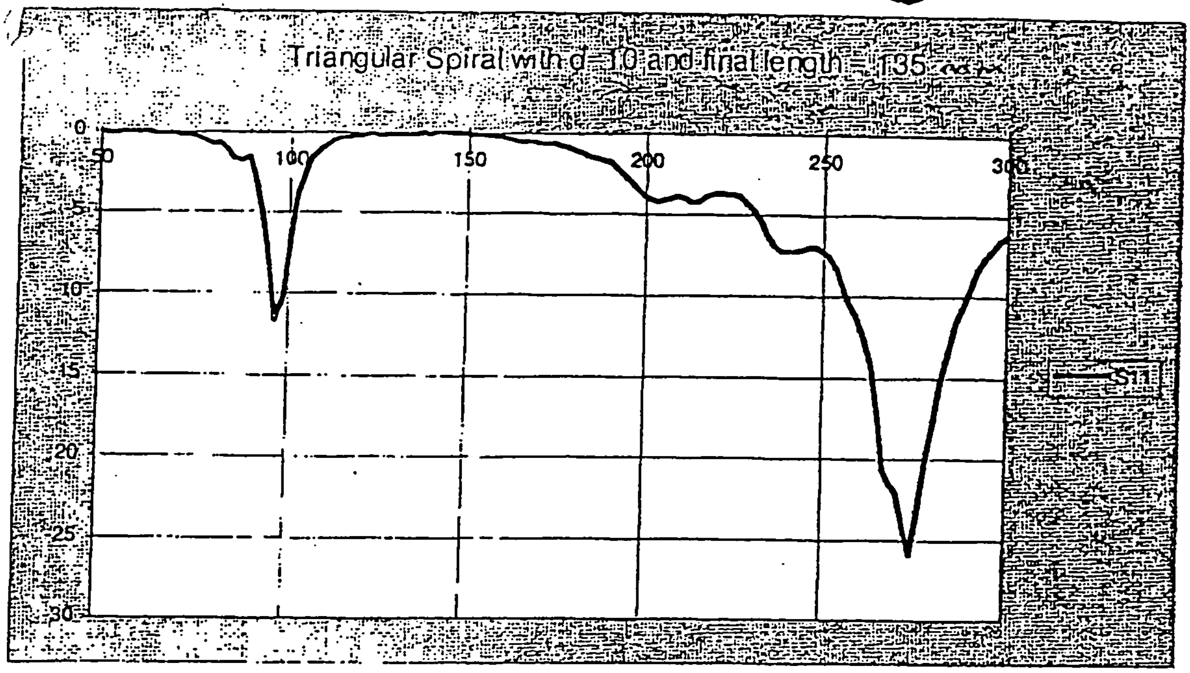

Fig 8a

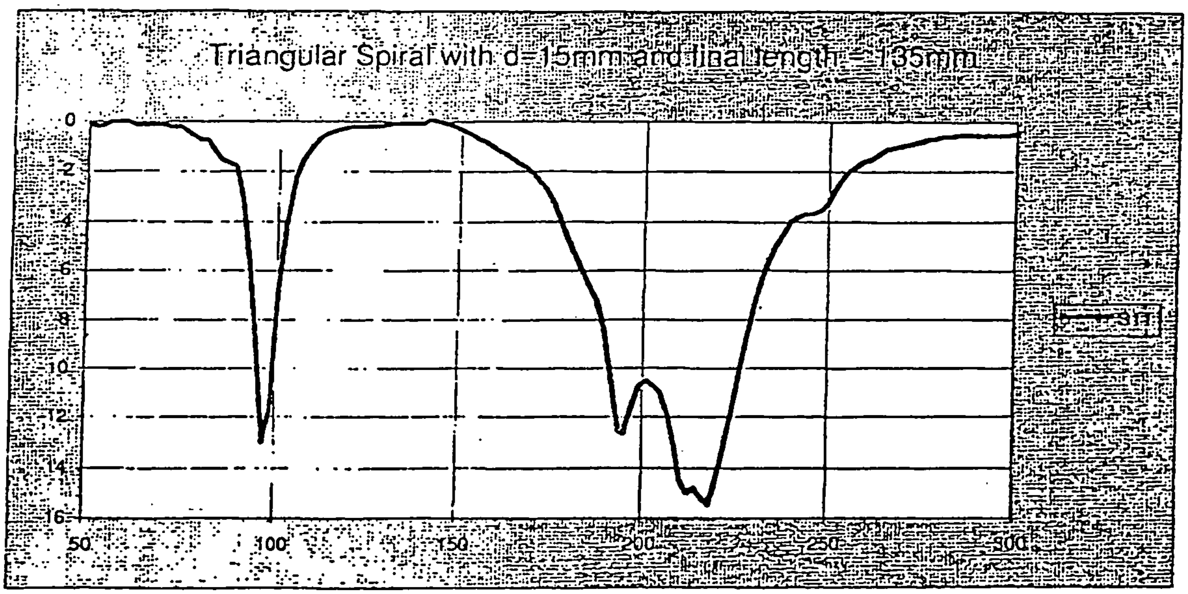

Fig 8b

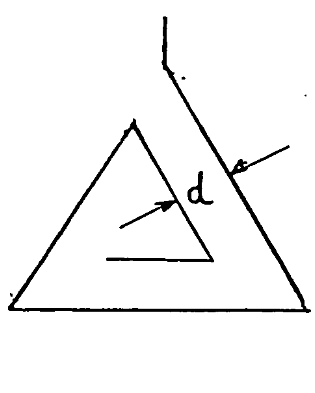

Fig 8c

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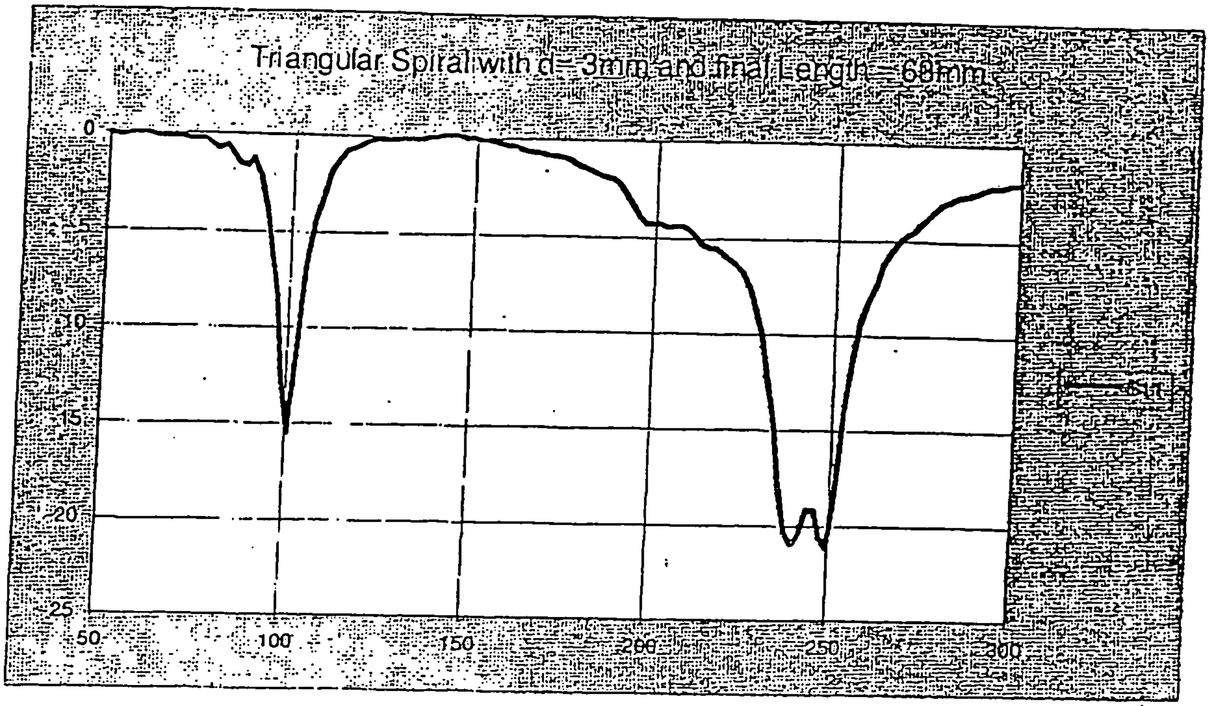

Fig 9

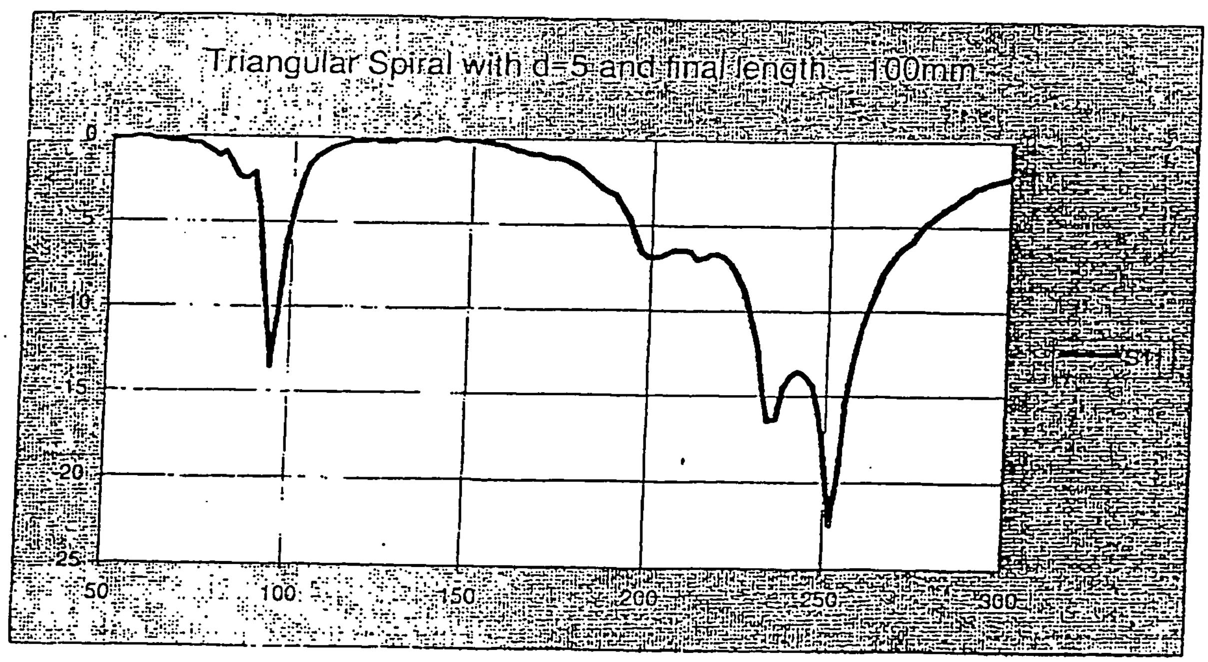

fig 10

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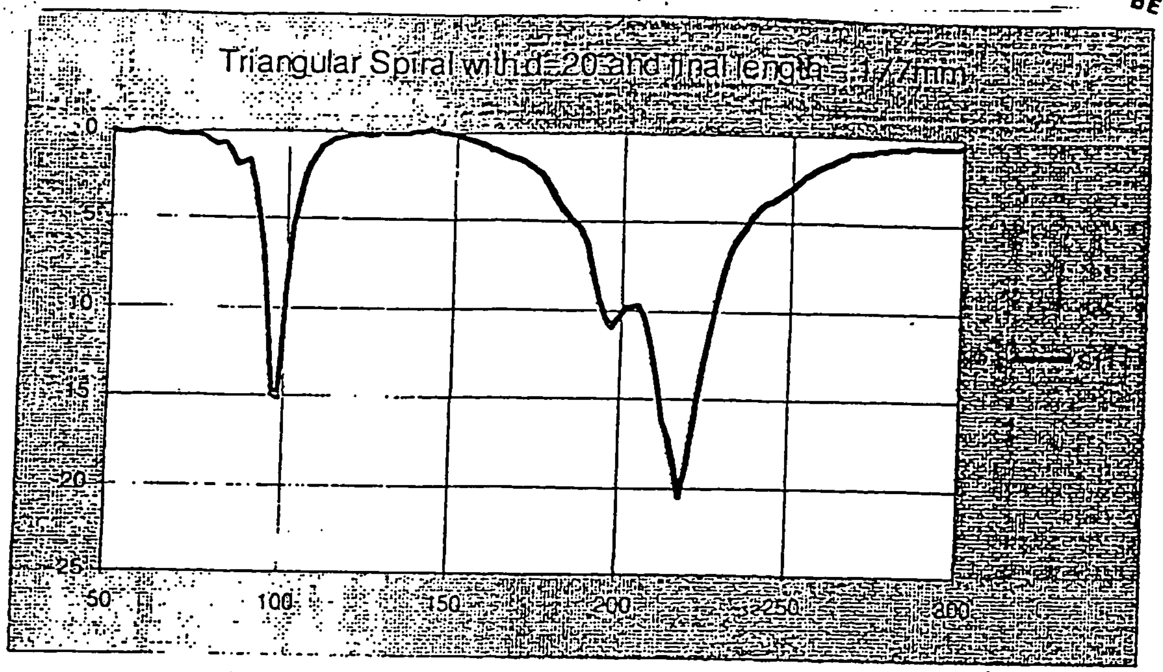

Fig 11

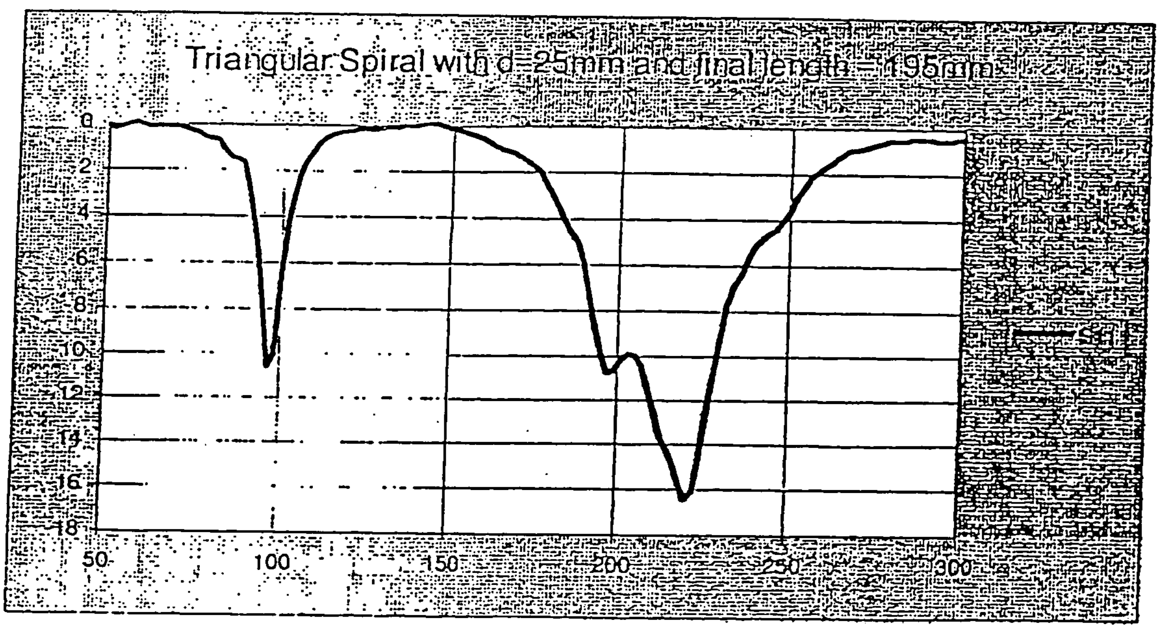

Fig 12